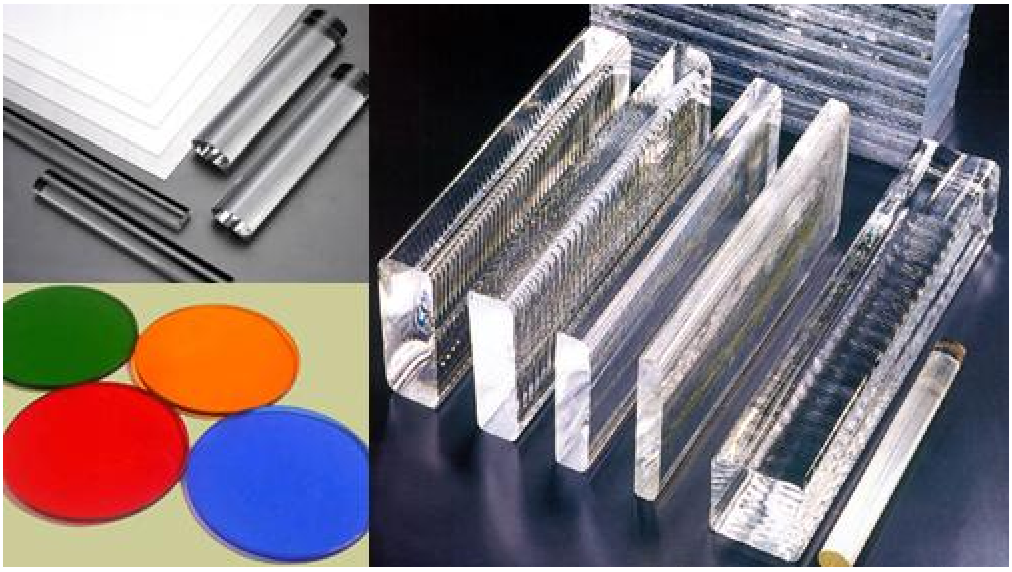
Some useful optical materials

Optical materials are fabricated into optical elements such as lenses, mirrors, windows, prisms, polarizers, detectors, and modulators. These materials serve to refract, reflect, transmit, disperse, polarize, detect, and transform light. The term “light” refers here not only to visible light but also to radiation in the adjoining ultraviolet and infrared spectral regions. At the microscopic level, atoms and their electronic configurations in the material interact with the electromagnetic radiation (photons) to determine the material's macroscopic optical properties such as transmission and refraction. These optical properties are functions of the wavelength of the incident light, the temperature of the material, the applied pressure on the material, and in certain instances the external electric and magnetic fields applied to the material.

There is a wide range of substances that are useful as optical materials. Most optical elements are fabricated from glass, crystalline materials, polymers, or plastic materials. In the choice of a material, the most important properties are often the degree of transparency and the refractive index, along with each property's spectral dependency. The uniformity of the material, the strength and hardness, temperature limits, hygroscopicity, chemical resistivity, and availability of suitable coatings may also need to be considered.



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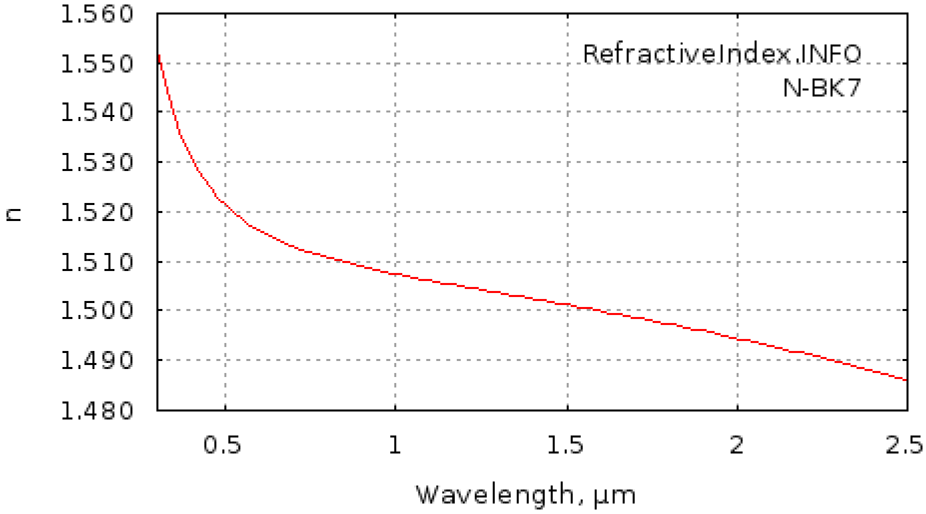
1. N-BK7(Schott optical glass)

Note: Equivalent material is H-K9L (CDGM optical glass)

Crown glass is type of optical glass used in lenses and other optical components.Crown glass is produced from alkali-lime (RCH) silicates containing approximately 10% potassium oxide. It has low refractive index (≈1.52) and low dispersion (with Abbe numbers around 60).

As well as the specific material named crown glass, there are other optical glasses with similar properties that are also called crown glasses. Generally, this is any glass with Abbe numbers in the range 50 to 85. For example, the borosilicate glass Schott BK7[1] is an extremely common crown glass, used in precision lenses. Borosilicates contain about 10% boric oxide, have good optical and mechanical characteristics, and are resistant to chemical and environmental damage. Other additives used in crown glasses include zinc oxide, phosphorus pentoxide, barium oxide, and fluorite.

A concave lens of flint glass is commonly combined with a convex lens of crown glass to produce an achromatic doublet. The dispersions of the glasses partially compensate for each other, producing reduced chromatic aberration compared to a singlet lens with the same focal length.



Sources: www.schott.com
www.cdgmgd.com

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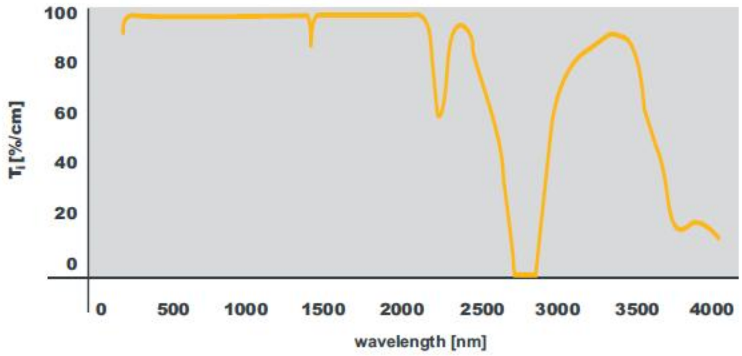
2. HPFS® Standard fused silica(Corning code 7980)

HPFS® Standard Grade, Corning code 7980, is a high purity synthetic amorphous silicon dioxide manufactured by flame deposition. The noncrystalline,colorless,silica glass combines a very low thermal expansion coefficient with excellent optical qualities and exceptional transmittance in the ultraviolet. It is available in a number of grades for different applications.



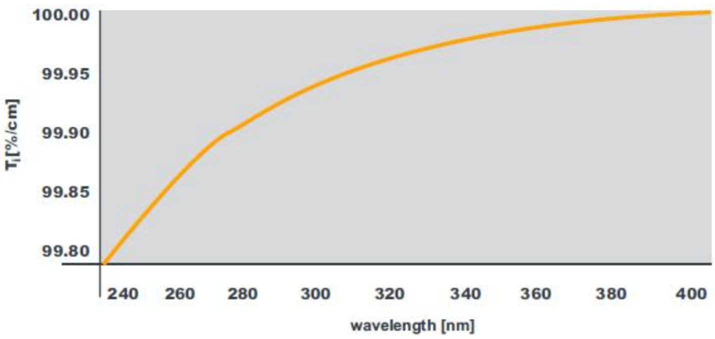
HPFS® Standard Grade is certified to meet T external ≥ 80%/cm @185nm (T internal ≥ 88%/cm @185nm), when measured through a polished, uncoated sample.

A typical internal transmittance curve for HPFS® Standard Grade fused silica is shown here.

Sources:www.corning .com

3. HPFS® KrF grade fused silica(Corning code 7980)

HPFS® KrF grade, Corning code 7980, is a high purity synthetic amorphous silicon dioxide manufactured by flame hydrolysis. The noncrystalline, colorless, silica glass combines a very low thermal expansion coefficient with excellent optical qualities and exceptional transmittance in the deep ultraviolet. KrF grade was developed for 248nm lithography systems.



HPFS® KrF Grade is certified to meet T_i ≥ 99.8%/cm@248nm when measured through a polished, uncoated sample. A typical internal transmittance curve for HPFS® KrF Grade fused silica is shown here.

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4. N-SF11(Schott optical glass)

Typically N-BK7 is used as the materical of choice.However, applications that require a better resolution,a higher refractive index material like the N-SF11 glass is beneficial.

Refractive index at 0.5876 μm: n = 1.78471

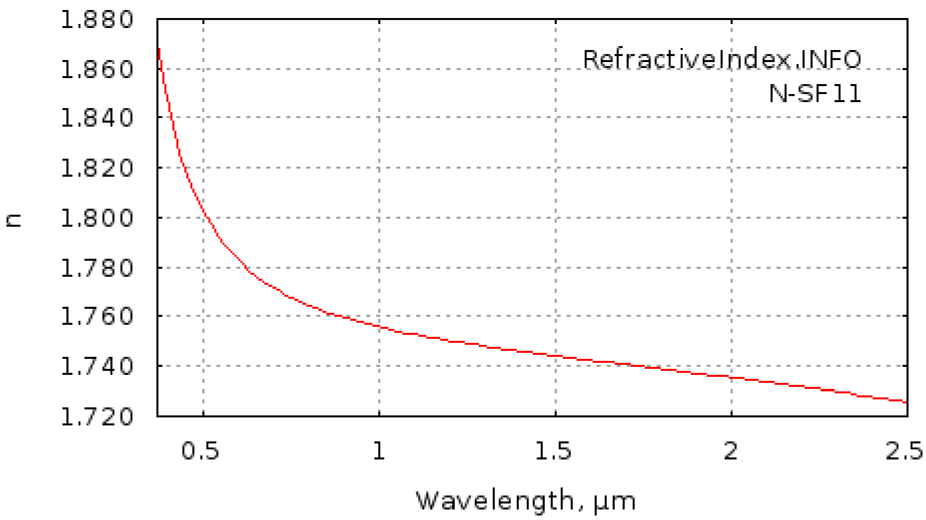
Abbe numbers: $V_d = 25.68$; $V_e = 25.47$

Dispersion formula:

$$n^2 - 1 = C_1\lambda^2/(\lambda^2-C_2) + C_3\lambda^2/(\lambda^2-C_4) + C_5\lambda^2/(\lambda^2-C_6)$$

$C_1 = 1.73759695$; $C_2 = 0.013188707$; $C_3 = 0.313747346$; $C_4 = 0.0623068142$; $C_5 = 1.89878101$; $C_6 = 155.23629$

Brewster's angle: $\theta_B = 60.737°$



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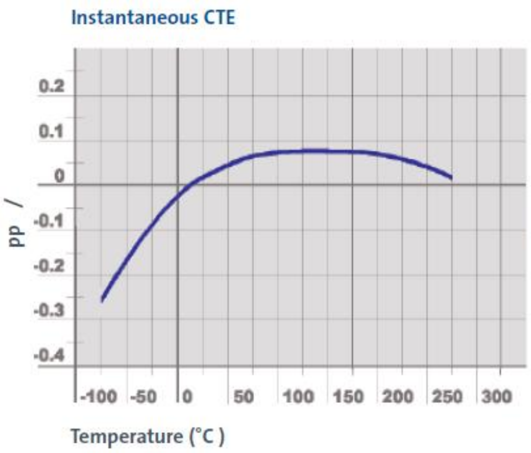
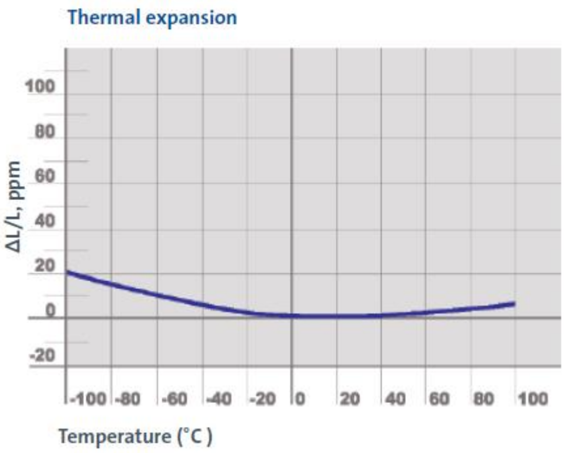
5. ULE Ultra low expansion glass(Corning code 7972)

ULE® Corning code 7972, Ultra low expansion glass is a titania silicate glass with unique characteristics that has made it the material of choice in applications ranging from machine tool reference blocks to solid and lightweight mirror blanks for astronomical telescopes and space satellite applications. Eeperts in the semiconductor industry have identified ULE® as a “material of choice” for EUV applications.





Thermal Properties

Mean coefficient of thermal expansion 5°C to 35°C ( )	0 ± 30 x 10^{-9}/K [0 ± 30 ppb/°C]	Mean specific heat (C_p)	767 J/ (kg • °C) [0.183 cal/(g • °C)]
Thermal conductivity (K)	1.31 w/(m • °C) [1.13 kcal/(m • hr • °C)]	Strain point	890°C [1634 °F]
Thermal diffusity (D)	0.0079 cm^2/s	Annealing point	1000°C [1832 °F]
D.C. volume resistivity, 200°C 100Hz (R)	$10^{11.6}$ ohm • cm	Softening point	1490°C [2714 °F]

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6. ZERODUR(Schott optical glass)

Zerodur is a glass-ceramic made by Schott AG. It has both an amorphous (vitreous) component and a crystalline component. The most important properties of Zerodur are:Nearly zero thermal expansion (≈0.02 × 10^−6/K at 0 °C–50 °C) with outstanding 3D homogeneity

Applications:

- Optics: Many optical devices such as telescopes and optical cavities require a substrate material with a near-zero coefficient of thermal expansion and/or excellent thermal shock resistance.
- Microlithography: Zerodur is used as a movable mechanical part in wafer stepper and scanner machines to achieve precise and reproducible wafer positioning. Zerodur is an ideal substrate material for reflective optics in the forthcoming EUV lithography due to its extremely low thermal expansion, outstanding homogeneity, and good processing behavior.
- Measurement technology: The extremely low thermal expansion and long-term dimensional stability of Zerodur make it an excellent reference standard for measurement instruments.

Properties

- Dispersion: (nf − nc) = 0.00967 ;Density: 2.53 g/cm3 at 25 °C
- Young's Modulus: 9.1 x 1010 Pa
- Poisson Ratio: 0.24
- Specific heat capacity at 25 °C: 0.196 cal/(g·K) = 0.82 J/(g·K)
- Coefficient of thermal expansion (20 °C to 300 °C) : 0.05 ± 0.10 × 10−6/K
- Thermal conductivity: at 20 °C: 1.46 W/(m·K)
- Maximum temperature: 600 °C

Sources: www.schott.com

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7. Germanium

Germanium is an important semiconductor material used in transistors and various other electronic devices. Its major end uses are fiber-optic systems and infrared optics, but it is also used for polymerization catalysts, in electronics and in solar electric applications.

Nature : infrared optical devices used for the crystal germanium. N-type conductivity. Hardness (Nupu) 7 ~ 8GPa. 102.7GPa elastic modulus, fracture modulus 75MPa. Heat capacity 0.32 / (g×K), thermal conductivity 60W / (K×m), the linear expansion coefficient of 5.50 × 10^-6 / μ m. With the infrared absorption coefficient of resistivity, wavelength and temperature change. The main window for the infrared laser, shrouds, low temperature detection devices windows.

	Physical Data & Typical Characteristics		
Mechanical	Density (298 K)	5,323 (± 0,001) x 10^3	kg/m^3
	Coefficient of compressibility	< 1,4 x 10^{-11}	Pa^{-1}
	Young's modulus (298 K)	10…15,5 x 10^{10}	Pa
	Torsion modulus (298 K)	6,8 (± 0,2) x 10^{10}	Pa
	Tensile fracture strength (298 K)	95 (± 16) x 10^6	Pa
	Microhardness H_K (25 g load)	780 (± 79) x 10^6	kg/m^2
	Microhardness HV (50 g load)	845 (± 30)	$HV_{0.05}$
Thermal	Melting point	1210,4	K
	Specific heat (273 to 373 K)	310	J/g.K
	Latent heat of fusion	36,945 x 10^3	J/mol
	Linear thermal expansion coefficient (300 K)	5,90 x 10^{-6}	K^{-1}
	Thermal conductivity (300 K)	60	W/m.K
Electro Magnetic	Dielectric constant ε (300 K)	16,2	
	Magnetic susceptibility χm (300 K)	-7,09 x 10^{-6}	
Optical	Refractive index n (293 K) λ (μm)		n (± 0,000 30)
		8	4,005 41
		9	4,004 12
		10	4,003 19
		11	4,002 48
		12	4,001 94
		13	4,001 51
		14	4,001 16
	Temperature coefficient of refractive index dn/dt at 293-298 K		
		0,0004 ± 0,00002	K^{-1}
	Refractive index variation within a component		
		monocrystalline	0,1 – 1 x 10^{-4}
		polycrystalline	0,5 – 2 x 10^{-4}
	Absorption coefficient at 293 K (laser calorimetry at 10,6 μm) typically		
		monocrystalline	≤ 0,020 cm^{-1}
		polycrystalline	0,020 – 0,035 cm^{-1}

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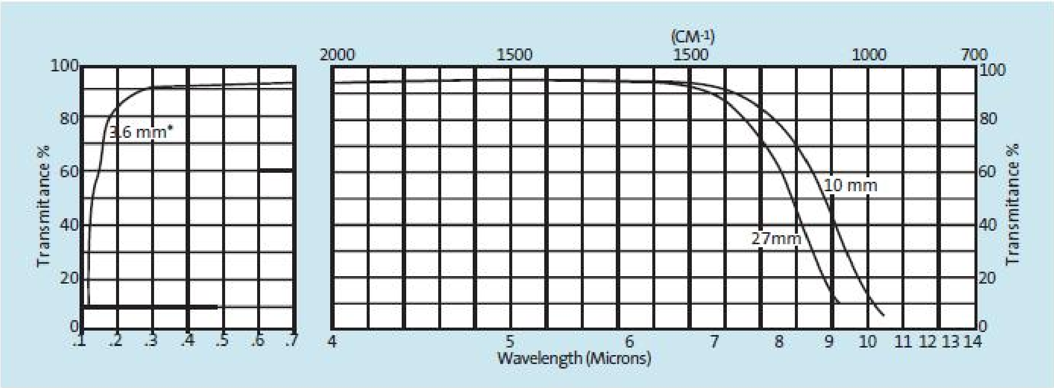
8. CaF2(Calcium Fluoride)

Calcium Fluoride is commonly used as a window material for both infrared and ultraviolet wavelengths, since it is transparent in these regions (about 0.15 μm to 9 μm) and exhibits extremely low refractive index. Furthermore the material is attacked by few reagents. At wavelengths as short as 157 nm, a common wavelength used for semiconductor stepper manufacture for integrated circuit lithography, the refractive index of calcium fluoride shows some non-linearity at high power densities which has inhibited its use for this purpose. In the early years of the 21st century the stepper market for calcium fluoride collapsed and many large manufacturing facilities have been closed. Canon and other manufacturers have used synthetically grown crystals of calcium fluoride components in lenses to aid apochromatic design, and to reduce light dispersion. This use has largely been superseded by newer glasses and computer aided design. As an infrared optical material, calcium fluoride is widely available and was sometimes known by the Eastman Kodak trademarked name "Irtran-3," although this designation is obsolete.

Transmission Spectrum



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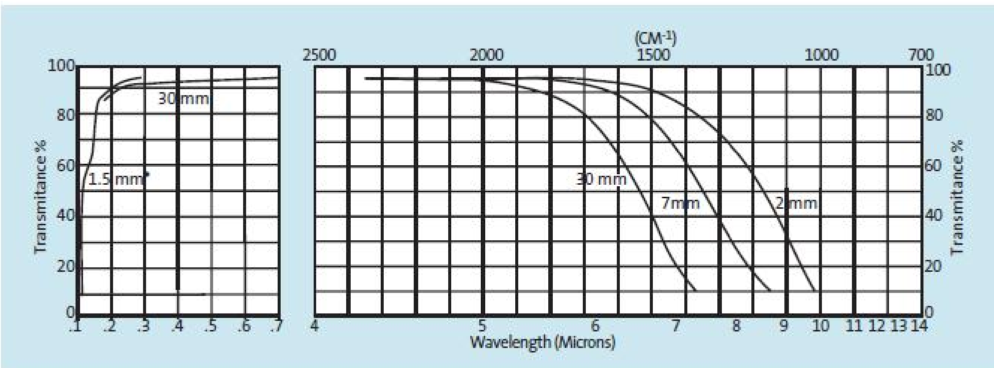
9. MgF2(Magnesium Fluoride)

Magnesium fluoride is transparent over an extremely wide range of wavelengths. Windows, lenses, and prisms made of this material can be used over the entire range of wavelengths from 0.120 μm (vacuum ultraviolet) to 8.0 μm (infrared). Lower grade MgF2 is sometimes used in the infrared but here it is inferior to calcium fluoride. MgF2 is tough and works and polishes well, but it is slightly birefringent and should be cut with the optic axis perpendicular to the plane of the window or lens.

MF2 along with CaF2 is a preferred material for UV laser use. Due to its chemical compsition MgF2 is good candidate for use in fluorine enviroments. Generally,material for laser use is recommended to be oriented along the optical axis to avoid birefringent effects.

Vacuum Ultraviolet Use: MgF2 is warranted to transmit at least 40% at 121.6nm for a 2mm path length.

Transmission Spectrum



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